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A SYNOPSIS OF MARINE ANIMAL UNDERWATER SOUNDS IN EIGHT GEOGRAPHIC AREAS

(10) William C. Cummings and James F. Fish

Naval Undersea Research and Development Center, Code 5054

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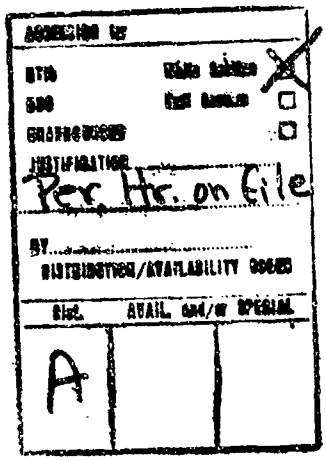

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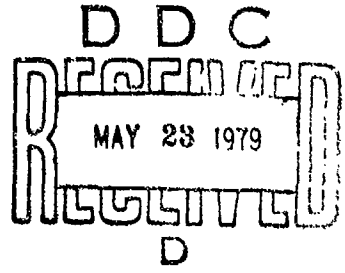

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INTRODUCTION

The purposes of this report are to list the soniferous marine animals that occur in eight geographic areas of interest, to rank them according to their importance as sound producers, and to describe certain features of their sounds. The geographic areas are identified in a separate enclosure that accompanies this report.

In preparing the information, over 200 papers were reviewed for their applicability to the general needs of the project. Although all of the data included here pertain to marine mammals, we would also expect to find soniferous fishes at all of these areas. However, information on fish acoustics is not presented for the areas, either because it was too scanty, or it did not exist. For the most part, fish sounds are relatively low-level transients that would not seem to apply to this problem. Elsewhere, certain species of fish are known to emit high-level choruses in the early morning or evening hours, but it is not known whether or not these phenomena also occur in the subject areas. The lack of sufficient information on the occurrence of fish sounds in the various key locations points out the need for more bioacoustics research in these areas. Even the available information on marine mammal sounds is far from complete. They warrant further study in these areas.

This list of soniferous marine mammals is divided into the PINNIPEDIA (comprising the seals--sea lions, fur seals, walrus, "true" seals, and hooded seals), SIRENIA (the dugong, related to the sea cow or the manatee), MYSTICETI (baleen whales without teeth, and the largest of the cetaceans), and the

ODONTOCETI (toothed whales, including the sperm whales and the porpoises).

Geographic regions are indicated as Roman numerals I - VIII. To rank the importance (based on population size alone) of the various soniferous marine mammals in each area we have used Arabic numerals 1 - 6, with the highest priority accorded to number 1 and the lowest to number 6. Final ranking in the "Summary and Conclusions" was a subjective procedure based upon the list of criteria included in the accompanying enclosure. These rank decisions were, in some cases, difficult to achieve. In general, they reflect the importance of a species according to its population size in a given area, in conjunction with its reputation as a sound producer. Consequently, a common species noted as a moderate sound producer could have received the same final ranking as a less common, but very soniferous species.

There was no attempt to give an exhaustive description of sound production and relative behavior for each of the soniferous marine animals presented in the section entitled "Pertinent Marine Mammal Sounds and Related Behavior". The index to this coverage appears by page number under "List of Marine Mammals of the World". We present this type of information in view of the original objectives as outlined by Charles H. Sturtevant, NUC Code 14. Further detail, such as spectrographic data, can be obtained when it is decided what species and areas are most pertinent to the needs of the project.

The indicated sources of magnetic tape recordings are ones that are familiar to the authors. Although most of these tapes are good quality recordings, they should not be construed as the only tapes of a particular recorded animal sound. We have reason to believe that the bioacousticians named here would entertain requests by NUC for duplicate recordings and perhaps supply their own data on sound analysis. In many of these cases the individual researchers have previously made tapes available to NUC Code 5054.

The reader will notice a complete lack of target strength data except for the sperm whale. However, we have indicated where classified TS data can be obtained for some of the species in the event it is required.

Among the whales, mysticete sounds differ from those of odontocetes by virtue of much lower frequencies and frequency range together with a decidedly greater source level. Conversely, the odontocete (or toothed whale) phonations extend as high as 200 kHz, perhaps higher. Generally speaking, the odontocetes as a group may be more vociferous than their toothless cousins, but they lack the power of the mysticete's utterances. A possible exception would be the presumed echo-ranging clicks from sperm whales which average 174 dB, re 1 $\mu N/m^2$.

We have included spectrograms representing the two basic types of mammal sounds--high (odontocete) and low-frequency (mysticete) utterances. Finally we present a brief summary of recommendations for each of the VIII geographic locations.

All of the sounds described for both large and small whales are underwater sounds. They were recorded with a hydrophone. Among the pinnipeds, or seals, we encounter sounds from the head of the animal that propagate in air and in water. For example, we have recorded strong barking sounds, underwater, from sea lions that were swimming with their heads up into the air. Presumably the throat and chest regions are well coupled to the water. Although the barks are <u>principally</u> made in air, they propagate even farther in water, often to great depths. Consequently, airborne sounds of seals also pertain to the objectives of the study and they are included along with the data on underwater sounds produced underwater.

LIST OF MARINE MAMMALS OF THE WORLD

(After Rice and Scheffer)

LIST OF MARINE MAMMALS OF THE WORLD continued

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RANKED DISTRIBUTION OF MARINE MAMMALS

IN AREAS I THROUGH VIII

AREA I - DISTRIBUTION OF MARINE MAMMALS

(1) HIGHEST PROBABILITY

Lagenorhynchus obliquidens - Common all around area. Large numbers.

(2) HIGH PROBABILITY

Phocoena phocoena

Eumetopias jubatus - Found near area in summer.

(3) POSSIBLE (GOOD CHANCE)

Phoca vitulina largha or Phoca largha - Tend to move north-south along shore.

Pusa hispida ochotensis - Probably spring.

(4) POSSIBLE (BUT NO GOOD RECORDS) (KNOWN FROM SEA OF JAPAN)

Orcinus orca - No good records from near vicinity.

Mesoplodon stejnegeri

Pseudorca crassidens

Grampus griseus

Neophocaena phocaenoides

Balaenoptera acutorostrata - Present April-May and Oct-Nov. (Known from Russian Coast)

Callorhinus ursinus

Balaenoptera physalus - Apr - June. Migrate through Sea of Japan.

(5) POSSIBLE (BUT RARE NOW)

Megaptera novaeangliae - Summer

Balaenoptera borealis - Summer

Eschrichtius gibbosus - Would be on location in April going north and Nov. and Dec. going south.

AREA I (continued)

(6) POSSIBLE (BUT NONE SEEN FOR YEARS)

Balaenoptera musculus - Jan - Mar. 50-100 mi. offshore.

Balaena glacialis - Jan - Sept.

Physeter catodon - Apr - June.

Zalophus californianus japonicus - May - July.

AREA II - DISTRIBUTION OF MARINE MAMMALS

(1) HIGHEST PROBABILITY

Delphinapterus leucas - Enters rivers in northern Sea of Okhotsk

(2) HIGH PROBABILITY

Phocoena phocoena

(3) POSSIBLE (GOOD CHANCE)

Eumetopias jubatus

Pusa hispida ochotensis

Phoca larga

(4) POSSIBLE (BUT NO GOOD RECORDS) (KNOWN FROM SEA OF OKHOTSK)

Orcinus orca

Delphinus delphis bairdi

Erignathus barbatus - Not gregarious. Small numbers. Shallow water.

Histriophoca fasciata

(5) POSSIBLE (BUT RARE NOW)

Balaenoptera physalus - June-Sept. Common in the Sea of Okhotsk.

Eschrichtius gibbosus - Used to be common in northern part of Sea of Okhotsk July-Sept.

(6) POSSIBLE (BUT NONE SEEN FOR YEARS)

Megaptera novaeangliae - Used to be very common. July.

Balaena mysticetus - Used to be very common. July-Sept., Jan.-Mar.

Balaena glacialis - Used to be common. July-Sept.

Balaenoptera acutorostrata

Physeter catodon - Was never very common in this area.

AREA III - DISTRIBUTION OF MARINE MAMMALS

(1) HIGHEST PROBABILITY

Eumetopias jubatus - All along coast. Breed during May-July.

Histiophoca fasciata - Densely distributed in adjacent area of Kamchatka. Found on pack ice.

(2) HIGH PROBABILITY

Phocoena phocoena - Common along shore.

Phocoenoides dalli - Widely distributed, but more offshore than Phocoena phocoena.

Delphinapterus leucas

(3) POSSIBLE (GOOD CHANCE)

Lissodelphis borealis

Berardius bairdi

Lagenorhynchus obliquidens

Balaenoptera physalus - Never before June or after November.

Physeter catodon - Never before May or after October.

Megaptera novaeangliae - Most frequent in July.

(4) POSSIBLE (BUT NO GOOD RECORDS) (GENERAL DISTRIBUTION INCLUDES KAMCHATKA ARE

Orcinus orca

Mesoplodon stejnegeri

Ziphius cavirostris

Globicephala macrorhyncha

Stenella caeruleoalba

Callorhinus ursinus

Phoca larga - Near shore.

Erignathus barbatus - Not gregarious.

Pusa hispida - (sub. kraschenninikovi)

AREA III (continued)

(5) POSSIBLE (BUT RARE NOW)---

Balaenoptera borealis - Small concentration in general area during June-Aug. Few above 50°N, never above 56°N.

Balaena glacialis - Now seen only occasionally during Apr - Sept. Used to be very common.

Balaenoptera musculus - Used to be common below 52°N, especially in June - July.

(6) POSSIBLE (BUT NONE SEEN FOR YEARS)

Balaena mysticetus - Oct - June.

Eschrichtius gibbosus

AREA IV - DISTRIBUTION OF MARINE MAMMALS

(2) HIGH PROBABILITY

Balaenoptera edeni - Coastal form.

Megaptera novaeangliae - Winter, early spring.

(3) POSSIBLE (GOOD CHANCE)

Physeter catodon - Most frequently during April-Sept.

Globicephala macrorhyncha

Pseudorca crassidens - Usually offshore.

(4) POSSIBLE (BUT NO GOOD RECORDS) (KNOWN FROM CARIBBEAN)

Delphinus delphis

Tursiops truncatus

Steno bredanensis

Stenella longirostris

Mesoplodon europaeus

Ziphius cavirostris

Orcinus orca

Balaenoptera physalus

AREA V - DISTRIBUTION OF MARINE MAMMALS

(1) HIGHEST PROBABILITY

Hyperoodon ampullatus - Present all months except Nov. - Apr., very common during July - Aug.

Lagenorhynchus acutus

Orcinus orca

Physeter catodon - Apr. - Sept.

(2) HIGH PROBABILITY

Globicephala melaena

Tursiops truncatus

Balaenoptera acutorostrata - All months except Aug, Dec, Jan, Feb. Most abundant in June - July.

Pseudorca crassidens

(3) POSSIBLE (GOOD CHANCE)

Megaptera novaeangliae - Feb. - April; June-Aug.

Balaenoptera borealis - Summer.

Phocoena phocoena

Cystophora cristata

(4) POSSIBLE (BUT NO GOOD RECORDS) (KNOWN FROM NORTH ATLANTIC)

Delphinus delphis

Grampus griseus

Balaenoptera physalus - Off Iceland in Mar., but the peak occurs in summer.

Mesoplodon bidens

Mesoplodon mirus

Stenella caeruleoalba

Halichoerus grypus

AREA V (continued)

(5) POSSIBLE (BUT RARE NOW)

Balaena glacialis - Used to be very common.

Balaenoptera musculus

AREA VI - DISTRIBUTION OF MARINE MAMMALS

(1) HIGHEST PROBABILITY

Delphinapterus leucas - In Apr.-June they move up Kola River. Present all months except July, Aug, Sept.

Lagenorhynchus acutus - All along Murmansk Coast.

Halichoerus grypus - Common off Murmansk Coast where they breed. No migration. Likely any time of year.

(2) HIGH PROBABILITY

Pagophilus groenlandicus - Common offshore. Moves south into White Sea in Oct.

Phocoena phocoena - Generally stay until late autumn or even the whole year.

Lagenorhynchus albirostris - Inhabits the waters of Murmansk.

Physeter catodon - Offshore, Murmansk Coast.

Balaenoptera acutorostrata - Present during June-Sept. Abundant in July and Aug. Not found during rest of the year.

(3) POSSIBLE (GOOD CHANCE)

Hyperoodon ampullatus - Sept. and Oct.

Stenella caeruleoalba

Fusa hispida hispida - Shallow water. Present in May-Oct., concentrating in May and June.

Orcinus orca - Present Aug.-Sept.

Odobenus rosmarus rosmarus - Shallow water, close to ice. Present in Sept., but not rest of the year.

Phoca vitulina - Good concentration throughout the year.

Cystophora cristata - Possibly June through Sept., and very common in Oct.

AREA VI (continued)

(4) POSSIBLE (BUT NO GOOD RECORDS) (KNOWN FROM BARENTS SEA)

Balaenoptera physalus - Present during Mar. - June.

Balaenoptera borealis - Probably offshore during warm months when there is no ice. Present during July through Aug.

Megaptera novaeangliae

Monodon monoceros

(5) POSSIBLE (BUT RARE NOW)

Balaena glacialis

Balaena mysticetus

Balaenoptera musculus

AREA VII - DISTRIBUTION OF MARINE MAMMALS

(1) HIGHEST PROBABILITY

Delphinapterus leucas - Present throughout the year, but most abundant Aug.-Nov. Very close to coast during winter.

(2) HIGH PROBABILITY

Pusa hispida - Common, chiefly in fast ice. Present June, July, and Aug.

Odobenus rosmarus - Shallow water near ice. Migrates north-south near edge of ice. Present all year, but concentrated in Mar., Sept., and Oct.

(3) POSSIBLE (GOOD CHANCE)

Phocoena phocoena - Summer only.

Balaenoptera acutorostrata - When there is no ice.

Pagophilus groenlandicus - Open water off east Novaya Zemlya. Move south to White Sea in fall. Breed in White Sea during Oct. Over 1 million in White Sea. Present Jan.-July, and Nov.

Orcinus orca

Balaenoptera physalus

(4) POSSIBLE (BUT NO GOOD RECORDS) (KNOWN FROM KARA SEA)

Hyperoodon ampullatus - Common on west side of Novaya Zemlya.

Balaenoptera borealis - Summer, July - Aug.

Balaena mysticetus

Megaptera novaeangliae

Monodon monoceros

Cystophora cristata - Frequently found on west coast of Novaya Zemlya.

Erignathus barbatus - Present July - Sept.

AREA VII (continued)

(5) POSSIBLE (BUT RARE NOW)

Balaenoptera musculus

AREA VIII - DISTRIBUTION OF MARINE MAMMALS

(1) HIGHEST PROBABILITY

Steno bredanensis - Very common. Schools up to 100. Coastal area, Gulf of Aden.

Physeter catodon - Probably year round.

Sousa plumbea - Schools of 2-5 common in Gulf of Aden.

Tursiops truncatus - Local common name is "Cowfish".

(2) HIGH PROBABILITY

Balaenoptera physalus - Mouth of Gulf of Aden, although more common farther East.

Balaenoptera musculus - Shallow water. Sept. Present size of population unknown. Used to be very common here.

Delphinus delphis

Phocoena phocoena

(3) POSSIBLE (GOOD CHANCE)

Neophocaena phocaenoides

Dugong dugon*

Grampus griseus

(4) POSSIBLE (BUT NO GOOD RECORDS, KNOWN FROM RED AND/OR ARABIAN SEA)

Orcinus orca

Megaptera novaeangliae

Balaenoptera edeni

Stenella dubia

Stenella longirostris

Pseudorca crassidens

AREA VIII (continued)

Globicephala macrorhyncha

Kogia breviceps

Ziphius cavirostris

Balaenoptera acutorostrata

*Only representative from Order Sirenia, although sea cows and manatees of other areas are soniferous.

SOUNDS AND BEHAVIOR OF PINNIPEDIA (SEALS)

Zalophus californianus--(California sea lion)

We know more about the sounds of the California sea lion than of all the rest of the seals. However, of the subject areas, this species is known only from area I where it used to be encountered in May - July. It is doubtful whether or not the California sea lion has survived in this area.

Should the study be widened to include the range of this species, there is plenty of bioacoustic data available. If this should be the case, this seal would be extremely important to the aims of the present undertaking.

Eumetopias jubatus--(Steller or northern sea lion)

The Steller sea lion is one of the largest seals, attaining a length of 10.5 ft at 2,240 lbs. Although it is reported to be extremely vociferous, both in the water and out, details are lacking. Growls, snorts, clicks, bleats, and other cries are produced, but we know nothing of source level, frequency characteristics or the time domain of the sounds. Vocalizations between pups and mothers, harem bulls and cows, and bulls confronting one another can be heard in the vicinity of these mammoth beasts.

Steller sea lions can dive for several minutes (at least to 600 ft) and may be found over a mile from shore where they raft up into groups of up to 100 individuals.

Because this species is abundant (up to 300,000 animals), widely distributed, and noisy, we recommend that detailed bioacoustics work be done in accessible areas such as Ano Nuevo Island. It is very common near area I in the summer, area II, and the best recommendation for area III where it is found all along the coast. The center of distribution seems to be the Aleutian Islands where there are up to 100,000 animals.

Tapes are available from Dr. T. C. Poulter, Stanford University; or from Dr. R. T. Orr, California Academy of Sciences.

Callorhinus ursinus--(northern fur seal)

Based on very little experimental evidence with captive specimens, this species is reported to make clicking sounds that apparently are used for echo-location. The source of the sounds is cavitation bubbles. These signals would not appear to be relevant to the present undertaking.

However, recordings in the field revealed that these animals produce strong bleating sounds and together, in a group, they would sonify the water appreciably. Other than the fact that some bleats are composed of clicks and that the bleats have numerous line spectra, there is no information about the physical characteristics including frequency range, source level, or temporal patterns.

Northern fur seals occur only at areas I and III. Dr. T. C. Poulter has recordings of this animal. These seals undertake very long migrations outside of the breeding season of June - July. However, they will range hundreds of miles from the beach in search of food while they still have pups. Target strength is unknown, but males may attain a length of 7 ft and a weight of 600 lbs. Fur seals are known to reach a depth of 180 ft.

Odobenus rosmarus rosmarus--(walrus)

Three types of underwater sounds have been described from the walrus--short rasping sounds, series of clicks, and a bell-like sound. Rasps have 4-10 pulses with the major energy at 400-600 Hz. They are about 0.15 sec in duration. The clicks have a base frequency of about 400 Hz with harmonics up to 10 kHz. The bell sound lasts 1-1.5 sec. Fundamental frequencies range from 400 to 1200 Hz. This category of walrus sound is believed to be associated with sexual behavior. Consequently, it would be most likely encountered during the breeding season, April - May. Source level is unknown.

Walruses stay near shallow water close to the coasts and do not venture far out to sea. Adult males are up to 12 ft in length and weigh up to 3,000 lbs. There is no information on target strength. Although one species is listed above, for which there is information on sound production, there are actually 2 subspecies rosmarus in the Atlantic and divergens in the Pacific. Both the Atlantic and Pacific walruses move north in the spring and south in the fall. Aggregations as large as 8,000 animals may occur in some areas. Although sounds have not been recorded in the natural habitat, among such large groups, there would appear to be a large potential for considerable underwater sound production in these locations. No information was available on their diving behavior.

Walruses are present during September in area VI. They occur in area VII all year, but are very common in March and again in the fall, September and October.

Magnetic tape recordings are available from Dr. C. Ray, Johns Hopkins; W. E. Schevill, Woods Hole Oceanographic Institution; and Dr. T. C. Poulter, Stanford University.

Phoca vitulina -(common, harbor, or spotted seal)

This species is closely related to the largha seal which some workers regard as a racial form of vitulina. The adult common seal is not regarded as being very vocal, but it is numerous in some areas. Pups are considered to be more vocal than the parents. Clicks and growls are known to be emitted by this species. Since the clicks, recorded in captivity, from the common seal are so similar to those of the largha seal, their description will not be repeated here. See the description under largha.

Common seals do not appear to migrate, but they do make forays in search of food and often away from the ice. This species may grow to about 250 lbs when about 6 ft in length.

Source levels, diving information, target strength, and temporal patterns of sound production all are unknown. Field work on the bioacoustics of the common seal should be undertaken since our information is limited to a brief recording in captivity. This seal is commonly found in area VI where there is a good concentration throughout the year.

Magnetic tape recordings may be obtained from W. A. Watkins or W. E. Schevill, Woods Hole Oceanographic Institution; or from Dr. C. Ray, Johns Hopkins University.

Phoca largha--(largha seal)

This species is sometimes considered to be a racial form of P. vitulina, but we treat it here as a separate species after Rice and Scheffer's listing. A captive largha seal was recorded in the presence of two other species and the sounds accorded to each were nearly the same. The largha seal emitted very faint clicks with major components at about 12 kHz.

This seal stays close to the edge of the ice. It is found at areas I, where it tends to move in north-south directions along the shore, II, and III.

There is no information on daily, monthly, or seasonal patterns of the animal's sounds, nor any on target strength. To our knowledge, the largha seal has never been recorded in the wild. Dive data are unavailable.

Magnetic tape recordings are available from W. E. Schevill and W. A. Watkins, Woods Hole Oceanographic Institution; and from Dr. C. Ray, Johns Hopkins University. However, by their description of the sounds it would seem that their tapes would not be very suitable.

Pusa hispida--(ringed seal)

Ringed seals are thought to produce bird-like chirps. A captive specimen voiced clicks that were often in pairs, Spaced 2 to 20 msec apart. Principal frequencies were near 4000 Hz and harmonics were present up to the sixth. There is no information concerning source levels or temporal patterns of sound, including daily, monthly, or seasonal occurrences.

Several subspecies of the above are recognized, but this subdivision may not be very important in the present undertaking.

Ringed seals are known to dive to 69 ft. They occur in the open waters near fast ice and in fjords, but rarely in the open sea. There is no information on target strength. These animals, compared with many of the other pinnipeds, are rather small -- 4.5 ft at 200 lbs. We actually have little idea of how important they may be as sound producers in the natural environment. However, bioacoustic studies of ringed seals should be undertaken as this species is numerous and widespread, occurring at areas I, II, III, VI, and VII. They are especially common at VII in June, July, and August.

Recordings of a captive specimen may be obtained from W. A. Watkins, Woods Hole Oceanographic Institution; or from Dr. C. Ray, Johns Hopkins University.

Halichoerus grypus--(gray seal)

Clicks up to 30 kHz have been recorded from captive gray seals. To our knowledge, there have been no recordings of wild animals. The clicks of the captive animals sometimes occurred in pairs about 0.01 to 0.02 sec apart, the pairs occurring at random intervals. Gray seals also issued series of clicks, up to 60/sec. There is no information on source levels or temporal patterns of occurrence.

This species does not migrate, but they do disperse after the breeding season (February and March, in the Baltic and St. Lawrence regions; September - December, in the British populations). Gray seals generally remain close to land masses and seldom venture very far to sea.

We know of no target strength data although the Oceanographic Office can be consulted on this species and for all pinnipeds. Adult males are up to 9.5 ft long at 630 lbs. Gray seals are mainly fish eaters and will dive to appreciable depths after their prey. There are records of gray seals diving to 480 ft.

Although we believe that gray seals are comparatively quiet, their reticence could possibly be offset by their commonness at area VI, where they may be found at any time of the year. They may be found at area V, but the records are incomplete.

Magnetic tape recordings are available from Dr. W. C. Cummings, NUC Code 5054; W. A. Watkins, Woods Hole Oceanographic Institution; or from Dr. C. Ray, Johns Hopkins University.

Histriophoca fasciata--(ribbon seal)

We know of no recordings from this beautiful seal although it is rather numerous, especially at area III. There is the highest probability of occurrence at area III, and recordings are badly needed. Ribbon seals are sometimes found at area IV.

In keeping with the dearth of bioacoustic information, little is known of the habits of ribbon seals. Target strength data are unavailable, the animals attaining a length of up to 6 ft at about 200 lbs. Although ribbon seals probably would move south with the ice in winter and north in summer, we only suspect they migrate. They stay close to ice and dive for fish, squid, and crustaceans, but we do not know how deep they dive, nor their diving patterns.

Pagophilus groenlandicus--(harp seal)

Clicks have been recorded from a captured harp seal. Harmonic structure occurred above a fundamental of 2000 Hz. The calls were similar to those of the ringed seal. The repetition rate was about 130/sec. There is no information concerning target strength, source level, or long-term temporal patterns.

Harp seals attain a length of about 6 ft and weigh close to 400 lbs. They occur in the open sea, often in association with ice, migrating north in summer and south in winter. Thousands of animals may be encountered in a group during the moulting season (April - May). Depth of dive and swimming speed are unknown.

Field recordings should be undertaken, because the harp seal is so numerous. Altogether there are about 5 million harp seals. They are common in area VI, and there is a good chance of finding them in area VII.

Harp seal recordings may be obtained from W. E. Schevill or W. A. Watkins, Woods Hole Oceanographic Institution; Dr. C. Ray, Johns Hopkins University; and from Dr. J. M. Terhune, University of Guelph, Ontario, Canada. Dr. Terhune may possibly have field recordings.

Erignathus barbatus--(bearded seal)

Mature male bearded seals vocalize during the breeding season, March - June. Their "song" is believed to be associated with the breeding activities, either in defense of territory or proclaiming the male's availability. These sounds are produced underwater. They start at about 2 or 3 kHz and end around 200 Hz. A single vocalization within a song lasts as long as 40 sec and the complete song, together with silent intervals, may be about 85 sec in duration. The song essentially consists of a long oscillating frequency-modulated warble followed by a moan. Diurnal patterns of sound production and the sound level are unknown.

The northernmost limit of the bearded seal is 80°-85° N, and they occur as far south as the Sea of Okhotsk. They are not found in large numbers except when hauled out on beaches. They stay close to shore or ice floes, and they attain lengths of 7.5 ft at 600 lbs. Bearded seals are curious animals and will approach ships making loud noises. Concerning the aims of this study, their lack of numbers in any one region would seem to be offset by the amount of underwater sound produced, even though they occur in relatively shallow water.

This species occurs at areas II, III, and VII. At the latter region they are most common in July - September.

Excellent magnetic tape recordings are available from Dr. J. J. Burns, Alaska Department of Fish and Game; W. A. Watkins, Woods Hole Oceanographic Institution; and Dr. C. Ray, Johns Hopkins University.

Cystophora cristata--(hooded seal; bladdernose seal)

The hooded seal is reputed to make broadband clicks extending from 0.1 to 16 kHz, but there appears to be very little information on its sonic output. The highest repetition rate observed was 20/sec. Hooded seals may also produce a narrowband click at 4 or 16 kHz. Acoustical information is too sparce to reveal source levels or temporal patterns. Apparently, no field recordings are available.

Adult males grow up to 900 lbs in weight at a length of about 10 ft. There is no information on target strength. Large groups of hooded seals are encountered in March and April, during the breeding season, and again in June and July when they assemble for moulting. The rest of the year hooded seals are pretty much solitary in behavior. They prefer to be over deep water and near drifting ice floes. A hooded seal pup is known to have dived to 246 ft.

The hooded seal population is very large, numbering some 300-500 thousand. If field recordings were to become available, this species may be important to this application. They occur at areas V, VI, and VII -- possibly June-September and definitely in October at area VI. Hooded seals are frequently found near VII.

Magnetic tape recordings are available from W. E. Schevill and W. A. Watkins, Woods Hole Oceanographic Institution; or Dr. C. Ray, Johns Hopkins University.

SOUNDS AND BEHAVIOR OF SIRENIA (DUGONG)

Dugong dugon--(dugong)

We do not know of any sound recordings of this species which is quite common in the general vicinity of area VIII. It probably makes sound but its habitat is in such shallow water (grassy areas) that it is unlikely to be important as far as this project is concerned.

SOUNDS AND BEHAVIOR OF MYSTICETI (BALEEN WHALES)

Balaena glacialis--(northern right whale)

The utterances from this whale are typically low-frequency moaning sounds with nearly all energy below 500 Hz. As in the humpback whale, northern right whale sounds may occur in repetitive stanzas lasting up to 14 min. In fact, the sounds are very much like those from the humpback whale, but lower in frequency. Each stanza consists of numerous, contiguous pulses and moans wherein upward or downward frequency shifts are common. The stanzas are repeated over and over again, resulting in a considerable amount of sound from a single animal. Other stanzas may be heard in the background of recordings from northern right whales.

The variety of sounds from northern right whales is reminiscent of sounds from the small odontocetes, but much lower in frequency.

Source levels, target strength, and long-term (daily, monthly, seasonal) patterns of sound occurrence are unknown for this animal. Nor is there any information on the precise tracks while the whale is diving.

Northern right whales can be found very close to shore where it is believed that they carry on courtship and breeding activities. At these times, they can be in groups of up to 200 animals.

This species is not very common in any area and it is not recorded from areas IV, VII, and VIII. It is a summer visitor to area III.

Tapes may be obtained from Dr. W. C. Cummings, NUC, and from W. E. Schevill, Woods Hole Oceanographic Institution. Features of the northern right whale's sound that make it applicable to the present problem are the repeated stanzas of many different components, rather precisely duplicated signal for signal.

Balaena mysticetus--(bowhead whale)

This species, sometimes called the Greenland right whale, is one of the 3 mysticete whales for which we have little or no information on sound production. It was reported that bowheads have a distinctive loud moan that shifts upwards or downwards in frequency. Each moan is restricted in bandwidth and may be longer than 10 seconds. The frequency range on sonagrams appeared to be from 20 - 2000 Hz, but it is difficult to see the signal apart from the noise. No evidence was given that the sounds were actually from bowhead whales and the frequency scale is incomplete.

Patterns of sound occurence, target strength, and source level are unknown. Bowheads may attain a length of 65 ft. They can sustain speeds up to 15 knots. Their diving behavior while underwater is unknown. This species stays very close to the ice pack and has been recorded from areas II, III, VI, and VII. Of these, it is most likely to be encountered in VII, but the records are far from complete.

This whale has been heavily exploited for nearly 300 years, and the population has dwindled under fishing pressure. There were several populations, but the taxonomy is poorly known.

Magnetic tape recordings are available from Dr. T. C. Poulter, Stanford University.

Eschrichtius gibbosus-(=robustus, glaucus) (gray whale)

For many years it was thought that gray whales were silent with the exception of splashes and other adventitious sounds. Then it was thought they produced trains of clicks, or random click pulses, and whistles. Clicks and whistles are not characteristic of mysticete, or baleen, whales and the evidence of these sounds having been produced by grays was unconvincing. Lack of success in recording was so overwhelming that it prompted one author to publish a paper entitled "The Quiet Gray Whale".

Since then we have found that migrating gray whales produce moans, underwater sounds associated with their blows, and knocking sounds. Moans last 1.5 sec; their source level is about 152 dB, re 1 $\mu N/m^2$ at 1 yd. These, their most common sound, range in frequency from 20 - 200 Hz. The underwater blow sounds, similar to those we have recorded from other baleen species, were 1.25 sec long, and they ranged in frequency from 15 - 175 Hz. Knocking sounds were as high as 350 Hz at source levels up to 142 dB, re 1 $\mu N/m^2$ at 1 yd.

Gray whales are soniferous during the day and night and there appeared to be no peak of sonic activity. Their average swimming speed while migrating from the Bering Sea and the Arctic Ocean is 5.5 knots. We were unable to associate any particular behavior with sound production. Gray whales dive as deep as 60 fa, and probably deeper. They occur in small groups of up to 5 or 6 animals, although one occasionally encounters singles.

This species is noted for its long migration from northern waters to the breeding grounds of Baja California. They occur in the north during the summer months, May - October. Compared with the odontocetes or the humpback whale, gray whales are not very soniferous, but are applicable to the present task, at areas I, II, and III.

Eschrichtius gibbosus (=robustus, glaucus) gray whale, continued

We do not know the target strength of gray whales, but W. Leapley, Naval Oceanographic Office, Washington, D. C. should be consulted for the most recent status on T. S. for this species. Gray whales may attain a length of 55 ft and a weight of about 48 tons. They can dive for as long as 14 - 15 min, but usually they stay down about 7 min. Occasionally one will see gray whales breaching -- a behavior wherein they extend the first 2/3 of the body and tumble down into the water creating a huge splash. This splashing sound is also audible from a hydrophone.

Magnetic tape recordings are available from Dr. W. C. Cummings, NUC Code 5054, and W. E. Evans, NUC Code 5023.

Balaenoptera acutorostrata--(minke whale; little piked whale)

This whale is not a very noisy animal. Many attempts to record sounds from the minke have resulted in very few phonations. Low-frequency moans have been recorded, but detailed information is not available yet. High-frequency clicking sounds were recorded in the North Atlantic, but this information is not available.

Target strength, dive profiles, depth of dive, and activity patterns are unknown at the present time.

The minke has a peculiar habit of being attracted to drifting, quiet, surface vessels and will cross back and forth under the bow of a ship for periods up to 2 hrs.

This species is reported to be from all areas except III and IV. It is rarely found in large groups. Thus, even when the animals do produce sound, it is unlikely that their utterances would occur in a large chorus.

Tapes may be obtained from W. E. Schevill, Woods Hole Oceanographic Institution; Dr. H. E. Winn, University of Rhode Island, Graduate School of Oceanography; Dr. E. Mitchell, Fisheries Research Board of Canada. None of these researchers has released any information on the sounds of minke whales.

Balaenoptera edeni--(Bryde's whale)

Bryde's whale is known to produce high-level, low-frequency moans that average 0.4 sec in duration, ranging from 0.2 to 1.5 sec, with energy concentrated at 124 Hz. The sounds have energy between 70 and 245 Hz. These low-frequency pulses commonly exhibit a shift in frequency of up to 15 Hz. The shifts may be downward, upward, or downward-upward. This whale was found to produce sounds at random intervals from 0.2 - 9 min, from a single animal. This species is not noted for large concentrations of individuals. It is generally encountered as an individual or in small groups. Choruses of sound are unknown, as true of target strength or long term periodicities in sound production. Moreover, nothing is known of dive profiles.

This animal can be very active, coming to the surface as often as every 5 min, or it can stay submerged up to about 20 min. It is common in area IV, often close to the coast, and infrequently encountered in area VIII.

Tapes are available from Dr. W. C. Cummings, NUC.

Balaenoptera borealis--(sei whale)

There have been no recordings from the sei whale, although NUC is planning to work with this animal off the coast of South Africa. It is known to occur at areas I, III, V, VI, and VII. There is a good chance of finding the animal at area V in the summer. Very little is known about the diving behavior of the sei whale. It can be found in small groups.

At with nost of the mysticete whales, the sei typically moves away from the polar ice during the winter and back to the polar waters in summer.

There is no information on the target strength of this animal.

Balaenoptera physalus--(finback whale)

Three categories of sounds are known from the finback whale--short 20-Hz pulses, low-frequency moans, and chirps and whistles. The 20-Hz pulses have a source level of 170-180 dB, re 1 $\mu N/m^2$ at 1 yd. Each pulse is about 1 sec in length, extending from about 15 - 34 Hz. They occur in pairs wherein the first member is slightly lower in frequency than the second. Time intervals are: from the start of the first to start of second pulse, 12.2 sec, and from start of second to start of first, 16.5 sec.

By virtue of their high source level and a chorus effect from numerous sound producers, these 20-Hz signals can dominate the low-frequency noise in the effective bandwidth. They are known to be most prevalent in the North Pacific during the winter months, although the sounds may very well occur throughout the year. American scientists have not been able to monitor polar waters in the summer. They have recorded from finbacks in the Gulf of California in the summer, but no 20-Hz signals were noted. Instead, low-frequency moans were prevalent.

Low-frequency moans from the finback whale varied in character, but all were about 0.5 to 2.5 sec in duration. Unlike the precise timing noted in the occurrence of short, 20-Hz signals, moans from the finback are sporadic in occurrence. The highest frequency containing any significant energy is about 200 Hz, the lowest is about 20 Hz. The moans were 55 - 60 dB, re 1 $\mu N/m^2$ at 1 yd. From a group of about 50 finbacks, as many as 80 moans were recorded in an hour's time.

Chirps and whistles were reported from finback whales, but there is some doubt that the signals described were from this species. Principal energies were at 1500 and 2500 Hz, some reaching as high as 5 kHz. The duration of the sounds varied between .05 and 0.6 sec. Source level of these sounds is unknown. These sounds are atypical of mysticete (baleen)

Balaenoptera physalus--(finback whale) continued

whales because of the high-frequency content of their energy. Thus we suggest that they could have been from unseen odontocetes in the general vicinity.

Dives to 276, 341, 443, and 755 ft are known to occur with finback whales, although they doubtlessly go deeper. The exact contours of the dives are unknown. These animals are more frequently found in small, widely dispersed groups. They have been noted in more compact groups of up to 70 animals. As true of all mysticetes, finbacks, at times, may only be encountered as they pass by on migration, or they may be seen rolling and feeding in a small area for many days at a time. These whales can easily move at 12 knots for periods up to 2 hrs. They can be very active at the surface, jumping and falling back into the water.

Target strength may be obtained from W. Leapley, Naval Oceanographic Office, Washington, D. C.

The finback whale has been noted at all subject areas, most commonly at areas III, VII, and VIII. Of all of the finned mysticete whales, this species is still the most numerous despite 200 years of hard exploitation by the whaling industry. However, a word of caution is in order--untrained observers frequently identify any darkly colored, large-finned mysticete as physalus, when in fact it may be sei, minke or Bryde's whale. The finback whale is the second largest of the whales and may attain a length of up to 70 ft.

Tape recordings are obtainable from Dr. W. C. Cummings, NUC Code 5054; P. Perkins, University of Rhode Island, Graduate School of Oceanography; P. Asa-Dorian, ASW School in San Diego; and from W. E. Schevill, Woods Hole Oceanographic Institution.

Balaenoptera musculus--(blue whale)

This animal produces powerful, low-frequency moans with each sequence consisting of 3 parts totaling 37 sec. in duration. While on a dive, the time duration from the start of one sequence to the start of the next averages 108 sec., but these intervals will stretch out to as long as 235 sec.-- as the animal comes to the surface to breathe it skips a phonation. Source level is about 180 dB, re 1 $\mu N/m^2$ at 1 m, and is sustained nearly continuously for the 37 sec. There is evidence of energy down to 12 Hz, but the moans have no energy above 200 Hz. These are the most powerful utterances known from whales or any other living animal.

Blue whales have been noted from all areas except II and IV, but are common only in area VIII. They most frequently occur as individuals or in small groups from 2 to 4 animals. They may stay in a given area or they may pass through an area at speeds up to 10 knots. Nothing is known of their diving profiles, nor is there any information on the daily, monthly, or seasonal patterns of sound production.

There are 2 reports of high frequency clicks from blue whales, but both involve questionable identifications. Continuous drones of moans have never been noted from blue whales.

Blue whales can attain lengths up to 108 ft. and it is common to find them as long as 85 ft. No information was available on target strength.

High signal-to-noise tapes of blue whale moans are available from Dr. W. C. Cummings, NUC Code 5054.

Megaptera novaeangliae--(humpback whale)

Of the 10 species of mysticete whales the humpback is the most notorious for its ability to produce underwater sounds. No mysticete, possibly excepting the right whale, has such a variety of underwater calls. The humpback's cacophony of howls, moans, grunts and pulses of low-frequency energy is spectacular wherever the animal is found. Taken together, its innumerable types of sound cover frequencies from about 20 to 2000 Hz with most of the energy below 900 Hz. Low-frequency tone bursts may be as short as 0.5 sec; the howls may last for several seconds. Frequency modulation is a common feature of humpback phonations.

Long-term recordings have been made in the vicinity of Bermuda, but no one has reported any diurnal periodicity. The sounds are seasonal in that they occur when the whales are in a given area, usually as they migrate past, between their summer sojourns to polar waters and their winter movements toward the subtropics and tropics. Diurnal information could be obtained from A. J. Perrone, U. S. Navy Underwater Systems Center, but he doubtlessly would have to work up his data for this purpose.

Humpback whales, as in the case of northern right whales, produce stanzas of varying phonations that are 8-9 min in length. The orderly occurrence of sound in stanzas is not apparent in real time analysis, but they are easily noted in spectrographic analyses that retain frequency and compress the time domain. We do not know if all sounds from humpback whales are put together in these repeated stanzas.

Source level of humpback whale sounds has been measured at about 55 dB, re 1 $\mu N/m^2$ at 1 yd. However, they may easily be 10 dB higher. Mr. W. Leapley, Naval Oceanographic Office, Washington, D. C., should have the target strength of humpback whales.

Megaptera novaeangliae--(humpback whale) continued

Humpbacks frequently occur in large groups of up to 15 individuals. Together, such a group puts an appreciable amount of sound into the water at any one time. They easily sustain speeds up to 15 knots.

This species is the most active of the mysticete whales. Its surface displays of jumping, rolling, and splashing are spectacular for such a large animal. Unlike many of the other baleen whales, by virtue of their surface activities, most humpbacks are easily spotted. On the other hand, the rest of the baleen whales may be very inconspicuous at the surface.

The greatest depth recorded for a humpback whale is 361 ft where a speciman had become entangled in an undersea cable off Alaska. The dive profile is unknown for this species.

The humpback whale is noted from all areas, but they are especially common in July at area III, winter and early spring in area IV, and February to August in area V.

Tape recordings are available from Dr. W. C. Cummings, NUC Code 5054; F. Watlington, Naval Oceanographic Facility, Bermuda; and Dr. H. E. Winn, University of Rhode Island, Graduate School of Oceanography.

SOUNDS AND BEHAVIOR OF ODONTOCETI (TOOTHED WHALES)

Steno bredanensis--(rough-toothed dolphin)

The rough-toothed dolphin produces both whistles and clicks. The whistles may be nearly pure tones or they may be quite complex with several harmonics. Most occur in a band from 2 - 16 kHz. The sounds may be from 0.1 to over 1 sec long. Rapid frequency excursions of the narrow-band whistles are common, sometimes sweeping from 14 kHz down to 2 kHz in about one-half sec. The clicks are extremely wide band and highly directional. Although some energy is as low as 2.7 kHz, peak energy occurs at 25 kHz in a fluctuating energy profile up to 260 kHz. They are very brief in duration, only 50 - 500 μsec. The repetition rate is regular over short time intervals, but can vary greatly over long periods of time or from one recording to the next.

The rough-toothed dolphin occurs only in tropical and warm temperate seas. It is not a very common species in most regions, hence we do not know much about its behavior in the ocean. It is primarily a deep-water species but occasionally it occurs in coastal areas. When seen at sea, it is difficult to follow even though it may occur in herds of up to 100 individuals. It travels submerged most of the time. Dives up to 15 min long have been timed by collectors from the Oceanic Institute in Hawaii. Apparently, it is a deep diver, based on its anatomy and on studies conducted on a captive, trained specimen. Although this trained animal only dove to 30 m, the investigators felt it was capable of much greater depths.

This species occurs in the coastal regions around area VIII and is probably quite abundant there at certain times of the year. However, much more research is needed for detailed information on the behavior of rough-toothed dolphins in this region. It could also be quite important at area IV, but pertinent data are even less available in this region.

Steno bredanensis--(rough-toothed dolphin) continued

Target strength is unknown for this species, but tape recordings of its sounds are available from Dr. K. S. Norris, Makapuu Oceanic Center, Hawaii; and W. E. Evans, NUC Code 5023.

Sousa plumbea--(plumbeous dolphin; lead-colored dolphin)

The plumbeous or lead-colored dolphins occur at area VIII. However, the sounds from these animals have not been described and their behavior is poorly known. It was reported that W. H. Dawbin, Sydney University, Australia, has recorded from this species, or at least from a closely related species of the same genus, but we have not been able to confirm this. If so, the recordings would probably be available to us.

Tursiops truncatus--(bottlenosed porpoise)

Bioacoustic studies on the bottlenosed porpoise probably exceeded those of all other species combined. However, most studies have been on captive animals. Their sounds may be placed in three general classes: whistles, broad-band pulses associated with echolocation, and high repetition rate broad-band pulses that result in signals which sound like barks or squawks.

The whistles are narrow-band signals which usually change pitch over their duration. They are generally less than 1 sec long but may occur in long trains. While the repertoire of a large herd is myriad and complex, individuals do seem to have their own whistle contours which they frequently repeat. Chorusing is common with large groups, and individuals within these groups seem to vocalize more than isolated animals or those in small groups. Most of the whistles occur in a band from 2 to 16 kHz. Rapid frequency excursions are common. For example, a whistle may slur from 12 kHz down to only 2 - 3 kHz in less than 0.5 sec. They often modulate from high frequencies to low, then back up to high. Other narrow-band whistles may remain at a constant frequency for 0.5 to 1 sec, then warble at the end of the signal for a tenth of a second or more. Clicks are often produced simultaneously with whistles.

The echolocation clicks are very short in duration, 50 - 250 μsec, have rapid rise times, and contain energy from 100 Hz to 100 kHz. The peak energy is generally in a band from 30 to 60 kHz. Pulses are emitted directionally with a 19 dB directivity index. Their source levels can exceed 70 dB, re 1 $\mu N/m^2$ at 1 yd. Clicks are frequently resolved into paired components whose peaks are less than 1 msec apart. The repetition rate can vary greatly, from about 40 to 600 clicks per sec. Apparently, bottlenosed porpoises have a lot of control over the frequency content of the clicks. They frequently shift from

Tursiops truncatus--(bottlenosed porpoise) continued

high frequency-rich signals to low frequency-rich signals and visa versa. Clicks that emphasize the lower frequencies have been termed orientation signals.

When the clicks are emitted at very high repetition rates (500 - 600 clicks/sec) for 50 - 100 msec, the resulting signals take on a complex tonal quality. With narrow-band analysis, they resolve into a fundamental, generally below 1 kHz, and several harmonics. These signals can sound like yelps, barks, squawks, buzzes, etc.

The bottlenosed porpoise, attaining a maximum length of 4 m, is an inshore or coastal form. At times, it may even be found in bays or river mouths. It is common in all tropical and warm temperate waters. This species is the most common cetacean exhibited at marine aquaria, the reason why so much is known of its behavior in captivity. Wild animals are very gregarious, occurring in herds of 100 or more individuals.

Individuals trained to dive to a target in the ocean have reached depths of at least 300 m. They remained down for 7 to 8 min. However, their diving capability in depth and time is probably greater.

This porpoise is rather easy to observe at sea and frequently rides the bow wave of boats. For short bursts it can reach speeds of about 18 knots, but a more normal cruising speed is 4 - 10 knots.

This is a very important species in areas V and VIII and probably in area IV. However, specific records are not available for area IV.

Target strength data for the bottlenosed porpoise may be obtained from Mr. W. Leapley, Naval Oceanographic Office.

Tape recordings are available from Dr. W. C. Cummings and Dr. J. F. Fish, NUC Code 5054; W. E. Evans, NUC Code 5023; W. E. Schevill, Woods Hole Oceanographic Institution; and many others.

Grampus griseus--(Risso's dolphin; white-headed grampus; gray grampus)

Risso's dolphin emits narrow-band whistles from 0.25 to 1 sec long. Most whistles fall in the 3 - 16 kHz range. Although they are narrow band at any given point in time, they may sweep over several thousand cycles during the course of the sound. They may be either relatively pure tone or have several harmonics.

Broad-band pulses of only a few msec duration are also produced by this species. Most of their energy appears to be below 10 kHz, but not enough field recordings have been analyzed to set definite limits at this time. We do not have source level data for this species and we do not know how vociferous it is in the wild. Click repetition rates can exceed 300 per sec.

This small whale, less than 3.5 - 4 m long, is widely distributed but not very common. Thus, we do not know much about its behavior. It is usually found alone or in small groups of less than 12. It spends considerable time on the surface then makes a long dive, probably deep.

There is a chance that we may find it at area I, V or VII, but we do not have good specific distribution data for the areas. The most likely location would be area VII.

Target strength data is probably not available, but magnetic tape recordings can be obtained from W. E. Schevill, Woods Hole Oceanographic Institution; and Dr. David K. Caldwell, Marineland Research Laboratory, University of Florida.

Lagenorhynchus albirostris--(white-beaked dolphin)

Sounds of the white-beaked dolphin are not expected to differ greatly from other Lagenorhynchus species. The 0.5 - 1 sec long whistles of this particular species seem to be restricted to a narrower band, 6.5 - 15 kHz, than those of the Atlantic white-sided dolphin, but this could be due mainly to insufficient sound recordings. We can probably consider most of the detailed information presented for the sounds of Lagenorhynchus acutus, and much of the behavior, to be valid for this species also.

The white-beaked dolphin frequently occurs in herds of greater than 1000 animals. For the most part it is known as a pelagic, or offshore, species, but it has been observed in the coastal waters of area VI. However, it is not likely to be found there in the winter.

Individuals range up to 3 m long and probably dive to 300 m. Target strength data for any species of Lagenorhynchus, or even Delphinus, would probably be very similar and might be obtained from Mr. W. Leapley, Naval Oceanographic Office.

Tape recordings of the sounds of this species are available from W. E. Schevill, Woods Hole Oceanographic Institution.

Lagenorhynchus acutus--(Atlantic white-sided dolphin)

The Atlantic white-sided dolphin emits whistles or squeals varying in frequency from 1 - 24 kHz. Some strongly modulated narrow-band whistles may change frequency by 12 - 16 kHz over a period of less than 0.5 sec. In many cases the whistles contain several harmonics and are actually broad-band clicks, with energy up to 150 kHz, emitted at very high repetition rates -- 80 to 200 clicks per sec. The clicks are only a few msec in duration. Other whistles, however, do appear to be nearly pure tones. These are not composed of clicks.

Source level measurements have not been made on this species, but estimates for a close relative, Lagenorhynchus obliquidens, are as high as 160 - 170 dB re 1 $\mu N/m^2$ at 1 yd.

This highly vocal species occurs in herds of up to 1000 individuals in coastal waters of the North Atlantic. It feeds primarily on migrating fishes; hence, its distribution can be fairly well predicted from the fishing statistics of an area. Although these porpoises are quite small, generally about 2.5 m in length, they are easy to spot because of their gregarious nature. They can probably swim in excess of 10 knots, and dive to 300 m or more. Target strength data may be available from Mr. W. Leapley, Naval Oceanographic Office.

The Atlantic white-sided dolphin is very common and abundant at areas V and VI, probably mostly during spring and summer, but possibly at any time when the coastal waters are ice-free.

Tape recorded sounds are available from W. E. Schevill, Woods Hole Oceanographic Institution; Dr. H. E. Winn, Graduate School of Oceanography, University of Rhode Island.

Lagenorhynchus obliquidens--(North Pacific white-sided dolphin)

The characteristics of the whistles and clicks produced by this species are similar to those for other Lagenorhynchus species. However, the clicks of L. obliquidens have been described in more detail. They are very short, only 0.25 - 1 msec in duration, and may be emitted at repetition rates of up to 500 per sec. The frequency range of the clicks extends from 60 Hz to 80 kHz but is centered in the band from 30 - 60 kHz. Whistles occur primarily in the 7 - 16 kHz band.

This species sometimes occurs in herds of thousands and frequents large bays and lagoons, particularly in the winter and spring. Their behavior is similar to the other two species of Lagenorhynchus discussed here. They are very easy to observe at sea, frequently jumping out of the water and commonly occur in mixed herds with Delphinus delphis.

This highly vocal species is very common at area I and is likely to be encountered at area III except during the winter.

Tape recordings are available from Dr. W. C. Cummings, NUC Code 5054, and W. E. Evans, NUC Code 5023.

Stenella longirostris--(long-snouted dolphin; eastern Pacific spinner dolphin)

Stenella dubia--(spotted dolphin; bridled dolphin)

Stenella caeruleoalba--(striped dolphin; euphrosyne dolphin)

We do not have enough specific details concerning the sound production and pertinent behavior of the Stenella species to discuss them separately. What follows is a collective description that should be valid for any of the three Stenella species considered in this report.

They all produce both whistles and clicks. Whistles and squeals are narrow-band sounds with principal energy anywhere from 2 to 28 kHz. They may sweep over several thousand cycles or remain at a relatively constant frequency for the duration of the signal, which may be from less than 0.25 sec to over 1 sec. The clicks are extremely short in duration; only 75 - 300 μsec. Their energy can span a frequency range from 100 Hz to 180 kHz.

The Stenella species are gregarious porpoises, often occurring in herds of hundreds. Chorusing is common with these species. They generally stay well offshore. Individuals are 2 - 3 m long, depending on the species. Their target strength is not known, but it should be similar to Delphinus delphis, based on size and body form. It is doubtful that they dive deeper than 300 m. They are usually easy to spot at sea. Some species jump completely out of water, and spin around on their tails before falling back into the water.

None of the species are very important in any of the areas considered in this report.

Tape recordings of Stenella sounds are available from W. E. Schevill, Woods Hole Oceanographic Institution; W. E. Evans, NUC, Code 5023; and Dr. K. S. Norris, Makapuu Oceanic Center, Hawaii.

Delphinus delphis--(common dolphin; saddleback dolphin)

The common dolphin is a highly vocal animal. Sometimes thousands of individuals make sound at the same time. Most whistles are in the 8 - 16 kHz range, but occasionally they may be as low as 2 kHz. Some complex whistles with numerous harmonics can have components up to 40 kHz. Other types of whistles are nearly pure tones at 8 - 16 kHz. The duration of the whistles varies from 0.5 sec to over 1 sec. Their frequency can either remain constant with time or sweep through several thousand Hertz.

A squeaking sound, composed of high-repetition-rate clicks, is commonly emitted. The maximum energy of this sound is from 4 - 9 kHz with up to eight harmonics at intervals of 1 kHz. These signals generally have several parts, each about 0.5 sec long.

Clicks, of 50 - 250 μsec duration thought to be used for echo-location, are produced at the rate of 5 - 250 per second. The repetition rate can either be constant or highly variable.

Frequency range of the clicks is from 100 Hz to 150 kHz with peak energy at 2 - 32 kHz. The source level of clicks from an individual is only about 140 dB re 1 $\mu N/m^2$ at 1 yd. However, since this species normally occurs in very large schools, higher group source levels may be expected.

Temporal patterns of sound production are presently being studied by W. E. Evans, NUC Code 5023. Apparently, there are diurnal and seasonal patterns. Whistles predominate during the day and clicks are more common at night. Large herds of several thousands of animals, found more often during the summer, whistle more than the smaller winter herds. Levels are higher during the day than at night.

Delphinus delphis--(common dolphin; saddleback dolphin) continued

This species is most common in deep water; however, on occasion it may range close to shore. Herds of several thousand animals are common, particularly in tropical waters. We do not know the seasonal distribution in any of the areas of interest. However, since the common dolphin feeds on pelagic fishes, we might be able to make some assumptions after reviewing the literature on the fishes of the areas.

The common dolphin is not a deep diver. It probably rarely exceeds 100 m, with most dives to less than 30 m. Dive times of 30 sec to 1 min are most frequent with an occasional dive of 5 min. In general, this species is quite easy to spot at sea as it frequently jumps clear of the water. It is a small cetacean, up to 2.5 m, but the fastest swimmer of all species, reaching 18 - 20 knots.

Target strength data for this species is available from W. Leapley of the Naval Oceanographic Office.

There is a very good chance that this animal may be found at area VIII year round and possibly also at IV.

Tape recordings are available from Dr. W. C. Cummings, Dr. J. F. Fish, and W. E. Evans, NUC; and W. E. Schevill, Woods Hole Oceanographic Institution.

Lissodelphis borealis--(northern right-whale dolphin)

We do not know of any sound recordings from this species, although W. E. Schevill, Woods Hole Oceanographic Institution, should be consulted for any new developments. There is a good chance of encountering the northern right-whale dolphin at area III, but little is known of its behavior.

It is doubtful if target strength information is available.

Pseudorca crassidens--(false killer whale)

The false killer whale makes both true whistles and clicks. Many of the whistles, which are primarily in a band from 3 to 12 kHz, are nearly single frequency sounds. There is very little change in pitch over the 0.5 to 1 sec duration of the signals. The clicks are a few msec long with energy from 100 Hz to 100 kHz. The repetition rate may be variable over long duration, but it is regular for short time intervals.

False killer whales are very abundant and have a world-wide distribution except for polar seas. It is a true oceanic species. Individuals frequently strand and die on the beach after chasing migrating fish or cephalopods in shallow water. They are very gregarious animals, occurring in herds of up to a thousand or more individuals. Based on their feeding habits, we would estimate they dive to about 500 m. However, there have been no scientific studies of their diving behavior. Although individuals may reach 6 m in length, they are not conspicuous at sea. Jumping or breaching is uncommon, and their swimming speed is unknown.

This species probably occurs frequently and in large numbers at area V. It could be present at any time of the year. False killer whales should also be common offshore from area III.

Target strength data may not be available, but tape recordings of their vocalisations can be obtained from W. E. Schevill, Woods Hole Oceanographic Institution.

Globicephala melaena--(common pilot whale; common blackfish; pothead whale)

This species, known as the common pilot whale, produces an almost unlimited variety of sound types. It vocalizes extensively, making both whistle and clicks. The whistles can be nearly pure tones or they may possess many harmonics. They may remain at a single frequency for longer than a second. Others may sweep over several thousand cycles, both up and down. In general, the energy is centered at some particular frequency band of 100 - 200 Hz, at a given time,with a range from 0.5 to 8 kHz. This species can also produce two, narrow-band whistles simultaneously with the two parts not harmonically related.

Short, broad-band pulses with most of their energy below 8 kHz, but extending up to well over 20 kHz, are produced either simultaneously with the whistles or alone. Their duration is only a few msec. The repetition rate is variable over long intervals, but regular over short intervals. It can range from 10 to over 50 pulses per sec.

Source levels are unknown, but from what we know of similar sized whales they probably exceed 160 dB, re 1 $\mu N/m^2$ at 1 yd. The levels of clicks are generally higher than whistles.

We know very little about the behavior associated with sound production or the frequency of occurrence of different signal types. At times, however, pilot whales do occur in very large herds of hundreds of animals and can be heard underwater from several miles away. Other groups may have only 5 - 10 individuals.

Globicephala melaena--(common pilot whale; common blackfish; pothead whale) continued

This species, probably dives to at least 300 - 500 m, but there are no detailed data on diving. On the surface, individuals blow 8 to 10 times then dive and stay down for up to 20 min. They do not jump or show their flukes, but are nevertheless quite easy to spot in large schools. Individuals may reach 6 m in length. The average swimming speed is 5 - 8 knots, but they can probably swim faster.

There is a tendency for this species to migrate, but we do not have data for area V, where we are most likely to encounter them. Target strength data for this species may be available from Mr. W. Leapley, at the Naval Oceanographic Office.

Tape recordings are available from Dr. J. F. Fish, NUC Code 5054; W. E. Schevill, Woods Hole Oceanographic Institution; and Dr. H. E. Winn, Graduate School of Oceanography, University of Rhode Island.

Globicephala macrorhyncha--(short-finned pilot whale; short-finned blackfish)

Like the common pilot whale, the short-finned pilot whale produces a great variety of signal types. Except for certain distinct whistles, which either species may produce, information presented for the common pilot whale will probably also apply to the short-finned pilot whale. Considering all signal types of both species, the greatest difference between species seems to be that some of the whistles of the short-finned pilot whale extend a little higher in frequency -- up to 13 - 14 kHz. From the limited published data, the clicks of the two species seem similar.

We can probably extrapolate information on the behavior, swimming speed and target strength for this species from that of the common pilot whale.

Orcinus orca--(killer whale)

Killer whales emit clicks in short bursts of 10 to 12 per burst. Click duration is between 0.5 and 1.5 msec, with peak energy at 16 - 20 kHz. Other, longer duration clicks, up to 25 msec, have most of their energy around 250 - 500 Hz. Killer whales are also noted for their "screams", basically of two types. One has a fundamental frequency of 500 Hz, the other at 2 kHz. Duration of the screams ranged from 0.1 - 3.0 sec with an average length of 0.65 sec. Killer whales are known to emit screams that are 4 - 5 sec in length, and energy has been recorded as high as 5 kHz. Estimates of source level range up to 78 dB, re 1 $\mu N/m^2$ at 1 yd.

These animals are nearly always found in small groups of 2 - 10 individuals, and they are extremely vocal. They commonly occur in shallow areas right up to the land interface, but they may be found well offshore. Killer whales make short dives of a few minutes duration. Although they may reach total lengths of up to 30 ft, most adults are 15 - 20 ft in length. Target strength is unknown.

Killer whales may be very active at the surface and can affect large disturbances. They are easily detected in a given area, not only by their multitudinous sound production, but by their high dorsal fins and frequent appearances at the surface. Even the casual observer would spot them easily.

All of the areas are known to contain killer whales, especially area VIII. Long-term recordings have not been made. Consequently, information on periodicity of sound production is not yet available. Because they are a serio predator on other marine mammals, including the huge mysticetes, playbacks

Orcinus orca--(killer whale) continued

of killer whale sounds will cause other whales to leave insonified areas. This has been shown with gray whales and white whales.

This species is very pertinent to the proposed undertaking. Magnetic tape recordings are available from Dr. W. C. Cummings, NUC Code 5054; Boeing Aircraft Corp., Seattle, Washington; and W. E. Schevill, Woods Hole Oceanographic Institution.

Phocoena phocoena--(harbor porpoise)

The harbor porpoise has a considerable repertoire of signals, representing various repetition rates that sound like long, frequency-modulated squeals (or whistles) which the animals accomplish by means of single clicks of short duration. Individual clicks, averaging 0.5 to 5 msec in duration, are narrow band with peak energy in the 1 to 3 kHz range. The energy does not exceed 20 kHz. Repetition rates are up to 1000 per sec, resulting in a modulated "whistle" sound with harmonics up to 6 - 8 kHz when analyzed with narrow filter bands. Pure-tone whistles have never been recorded from this species. Source levels are only 25 - 30 dB, re 1 $\mu N/m^2$ at 1 m.

The harbor porpoise, about 1.5 m long, has a wide geographic distribution and may be important in all the areas considered in this report except IV. This species occurs in the coastal zone, avoiding the open sea, and quite frequently enters rivers. Rarely is it found farther than 1 km offshore. Normally harbor porpoises occur in small groups of 2 - 10 individuals, but they may aggregate in large schools during fish runs. It is a slow swimmer, does not jump out of the water, and does not produce a visible spout.

Target strength of this species is probably available from Mr. W. Leapley, Naval Oceanographic Office.

Tape recordings of sounds from the harbor porpoise are available from Mr. P. Perkins, Graduate School of Oceanography, University of Rhode Island; and W. E. Schevill, Woods Hole Oceanographic Institution.

Neophocaena phocaenoides--(black finless porpoise)

Short duration clicks but no whistles have been recorded from the black finless porpoise. Most of their energy is contained in a band from 40 Hz to 12 kHz. Source levels are probably quite low.

This very small porpoise, less than 1.5 m in length, is a coastal species which often swims miles up rivers from the sea. Infact, in some Chinese waters they go several hundred miles inland. In coastal waters they prefer shallow water among islands and reefs. Most often they occur alone or in groups of 4 or 5 individuals.

Tape recordings of their clicks are available from W. E. Schevill, Woods Hole Oceanographic Institution; and W. E. Evans, NUC Code 5023.

Phocoenoides dalli--(Dall's porpoise; white-flanked porpoise)

Dall's porpoises emit clicks of 0.5 to 5 msec that are much like those of the harbor porpoise. There is very little energy above 20 kHz. They are not known to produce pure tone whistles. Signals that sound like squeals or whistles are actually short duration clicks emitted at very high repetition rates of up to 1000 per sec. On the other hand, the repetition rate can be as low as 15 per sec.

This species is quite common in certain areas of the North Pacific. They possibly occur in areas I and II, but we did not list them for these regions for lack of reliable data. They should be numerous at area III, probably year-round. They may be found in groups of 3 - 5 or even up to 200. This small porpoise, less than 2 m long, may be found anywhere from bays and inlets to 20 miles offshore. On rare occasions, they are hundreds of miles from land.

Dall's porpoise is a "playful" species. It frequently breaches, making it easy to spot at sea. Maximum swimming speed is unknown.

Target strength is not known, but it would probably be very similar to that of other species of this general size. Tape recordings of its vocalizations are available from Dr. W. C. Cummings, NUC Code 5054.

Delphinapterus leucas--(white whale or beluga)

The beluga is probably one of the most important marine mammals considered here. It is very abundant in areas II, III, VI, and VII. In fact, of all species it is the one most likely to be encountered at II, VI and VII. Sound production has evolved in the beluga to a point which makes it the most vociferous marine animal. Old whalers called it the sea canary.

The variety of signal types is almost endless. Included are high-pitched, resonant narrow-band whistles and squeals, various broad-band click sounds, chirps, mews, and jaw claps. The narrow-band whistles can sweep either up or down in frequency with time, but most sweep down. The frequency range is from 1 to 10 kHz, duration from 0.1 sec to 1 sec. Some whistles are amplitude modulated with a principal frequency in the 2 - 5 kHz region, and there are several concurrent sideband frequencies.

Short yelps are one of their most common signals. They average 50 - 150 msec long, sometimes occurring in trains of four or five. Fundamental frequencies of these complex sounds occur between 1 and 3 kHz with as many as 10 harmonics extending to 13 kHz. Numerous other types of complex sounds have been described from captive animals, but few sounds of wild animals have been analyzed.

Clicks, thought to be used for echolocation, are produced frequently, at widely varying repetition rates. At slow repetition rates, the clicks are discrete events, but at fast rates they sound like the squeaking of a rusty hinge. Pulse trains may last up to 30 sec with repetition rates from 15 to 210 pulses/sec, but primarily 20 to 60 pulses/sec. Most of the energy is between 12 - 30 kHz. Click duration is about 5 msec.

Delphinapterus leucas--(white whale or beluga) continued

Our own estimates of source level for sounds from an individual whale are approximately 145-155 dB, re 1 $\mu N/m^2$ at 1 yd. However, belugas are normally found in very large groups. Source levels of these noisy herds may exceed 160 dB. Different sounds are associated with different behaviors, but there is no obvious periodicity of sound production, either daily or seasonally. Sound is produced by at least some individuals in the herd almost at all times. There are, however, periods when numerous individuals, or even the whole herd joins in to create a roaring outburst.

This species is one of the most common Arctic animals occurring in herds of thousands covering vast areas of the ocean. In fact, schools of over 10,000 have been observed. They prefer temperatures below 60°F. They are basically a shallow water species, rarely over two miles offshore. Frequently, entire schools will go 10 - 20 miles up rivers; they do this at area VI. At area VII they actually go through the straits. Belugas do not enter rivers which are full of ice. Swimming speed, depending on behavior, varies from 1 - 10 miles an hour. Moving calmly at 3 - 5 miles an hour, a beluga surfaces every 1 - 1.5 min, and once frightened every 3 min. Most dives are less than 2 min long, but they can remain down for over 10 min. The whales rarely dive beyond 12 m, but can probably go to over 50 m. No good data exists.

In general, the animals, averaging 14-16 ft. long, are quite easy to spot because of their very white color. When scared, however, they can become less obvious by staying well below the surface.

Seasonal detailed migration data for certain areas is available from NUC Code 5054 and should be considered.

Delphinapterus leucas--(white whale or beluga)-continued

Outstanding tape recordings are available from Dr. J. F. Fish, NUC Code 5054; Dr. H. E. Winn, University of Rhode Island, Graduate School of Oceanography; and from W. E. Schevill, Woods Hole Oceanographic Institution. Target strength data is not available.

Monodon monoceros--(narwhal)

The narwhal, noted for the long spiral tooth that extends forward of the male up to 8 or 9 ft, produces clicks, pulses, and short squeaks. The clicks occur in series at various repetition rates. The frequency range of narwhal sounds is up to 24 kHz. Clicks occur as often as 100/sec. Squeaks are narrow-band tones that shift upwards or downwards in the frequency range between 5 and 10 kHz. A considerable amount of sound results from large groups of narwhals producing overlapping signals.

There is no information on source level, nor any information on long-term patterns of sounds from this species. The nearly constant repetition rate and frequency suggests that the sounds are not used for echolocation. Instead, it has been suggested that they may be of communicative function. Target strength of narwhals is unknown, but W. Leapley of the Naval Oceanographic Office should be consulted for the possibility that this information has been recently obtained. Narwhals may reach 16 ft at full growth.

Narwhals are known to descend to 1200 ft. They frequently occur in groups of 6 to 10 animals, but a group may number up to 50. They have been described as quick, active, and inoffensive. These whales generally stay close to the edge of the ice, but stragglers have been seen far from the ice. They occur at areas VI and VII, but the records are incomplete.

Magnetic tape recordings of narwhal sounds are available from W. E. Schevill, Woods Hole Oceanographic Institution; and Dr. C. Ray, Johns Hopkins University. Together with W. E. Watkins these researchers have the only known recordings from the narwhal, but they feel that this species may have a much larger repertoire of sounds. The narwhal is related to the white whale treated elsewhere in this report, a fact that may be very important since the white whale is one of the most vociferous of all the marine mammals.

Physeter catodon--(sperm whale)

The sperm whale, largest of the odontocetes or toothed whales, is well known for its production of trains of clicks, presumably for echo-ranging. The clicks are as high as 174 dB, re 1 $\mu N/m^2$ at 1 yd with most of the energy below 10 kHz, some as high as 32 kHz. Sperm whales change the repetition rate of their clicks which vary from about 1 click/sec to as many as several hundred/sec. Each click is composed of a number of short pulses of up to 2 msec long. Sperm whale clicks are very characteristic and in most instances these whales can be identified on the basis of sound alone. The typical lowest limit of the clicks is at about 200 Hz.

Squawks, rasps, yelps and even whistling sounds have also been reported from sperm whales, but their occurrences are unusual. It is believed that reports of some of these sounds may have involved inaccurate identifications, the sounds actually being emitted from another biological source.

Sperm whales most frequently occur in groups consisting of females and a lead male. Males without harems may travel in groups or singularly. Large groups of sperm whales can number up to many hundreds of individuals that are frequently subdivided into subgroups or harems. As such, they can produce a tremendous amount of underwater sound and are certainly relevant to the current problem.

Unlike finned whales, the presence of sperm whales is generally easily revealed due mostly to their antics at the surface. Lobtailing and breaching add to their conspicuousness. On the other hand, when only a few animals are present, they can be difficult to spot. This species holds the record among whales for the length of dive--up to 90 min. Dives of 1 hr are common. Ashley's rule states that a 60-ft sperm whale will stay submerged

Physeter catodon--(sperm whale) continued

for 60 minutes; it will weigh about 60 tons, and will spout about 60 times. No doubt, this is a rather loose generalization. There is unpublished data showing that a sperm whale reached the 7200-ft depth while on a dive. This is about twice the depth where a sperm whale had become entangled in a cable.

Target strength at 1 kHz is between 106 and 107 dB, re 1 $\mu N/m^2$, "bow aspects." Beam estimate is about 100 to 110 dB.

Sperm whales can put on bursts of speed up to 12 knots, but they more frequently travel at average speeds of 4 - 5 knots.

This species has been seen at all areas except for VII. They are very common at area V (April - September), VI and VIII (year round). Unlike many of the large and small whales, sperm whales are rarely seen near the coast. They more typically occur in the open ocean out to mid-oceanic regions.

Tape recordings of sperm whale sounds are available from Dr. J. F. Fish, NUC; W. E. Schevill or Dr. R. H. Backus, Woods Hole Oceanographic Institution; P. Perkins or Dr. H. E. Winn, University of Rhode Island, Graduate School of Oceanography; and W. Whitney, Marine Physical Laboratory, University of California, San Diego.

Kogia breviceps--(pygmy sperm whale)

The only sounds recorded from the pigmy sperm whale have been very faint clicks with a frequency range of 40 Hz to 5 kHz, with very little energy above 2 kHz. Source levels are not known, but must be very low. The signals have only been recorded by use of a contact microphone on an animal out of water.

This species has a wide distribution, particularly in tropical waters, but is quite rare. The animals are solitary or congregate in small groups. Maximum size is 3.5 - 4 m; target strength is not known. Very little is known about the behavior of this species except that it is slow moving and may come to within 200 m of shore.

Tape recordings of sounds recorded at sea are not available. However, recordings of the above sounds are available from Dr. D. K. Caldwell, University of Florida.

Mesoplodon bidens--(North Sea beaked whale)

We do not know of any sound recordings from this quite rare species which shows up infrequently at area V. Very little is known of behavior pertinent to this undertaking and we doubt that there is any information on target strength.

Mesoplodon europaeus--(Antillean beaked whale)

We do not know of any sound recordings from this rare species which occurs infrequently at area V. Very little is known of the animal's behavior that is pertinent to the present study.

We doubt that there is any information on the target strength of the Antillean beaked whale.

Mesoplodon mirus--(True beaked whale)

We do not know of any sound recordings from this species which occurs infrequently at area V. Very little is known about the behavior of this animal and we doubt if target strength has been determined.

Mesoplodon stejnegeri--(Bering Sea beaked whale)

We do not know of any sound recordings from this species which occurs infrequently at areas I and III.

We know nothing of its relevant behavior and doubt very much if target strength data are available.

Ziphius cavirostris--(goose-beaked whale; Cuvier's whale)

The goose-beaked whale is known to produce whistles and other types of sounds. However, these signals have only been verbally described by whalers and other observers of beached whales. There are no scientific descriptions of the different sounds.

There is very little known about the behavior of this species. It is cosmopolitan, except for high latitudes. Most often, it occurs only in oceanic waters, but occasionally it may move in close to shore. Groups of about 2 - 7 individuals are most common. They remain on the surface for about 10 min, then sound together, and remain down for 1/2 hr or longer. They are probably deep divers. Goose-beaked whales can attain a length of 8 - 9 m.

They are known from the general regions of the world encompassing areas III, IV and VIII, but there is no specific data for the regions.

The target strength of this species is unknown. Tape recordings of their sounds are not available at this time.

Berardius bairdi--(North Pacific giant bottle-nose whale)

We know of no scientific reports on the sound production of the North Pacific giant bottle-nose whale. A closely related species, Berardius arnouxi, is known to make a sound "like the bellowing of a bull", but the characteristics of these sounds have not been described.

The North Pacific giant bottle-nose has never been seen nearer than 10 miles from the shore. There is a slight possibility of it showing up at area II and a fairly good chance of seeing it at area III, arriving there in April - May and migrating south out of the area by November.

The behavior of this species is not well known since it is not very common. Generally, they are seen in tight schools of 20 - 30. Individuals stay on the surface 3 - 7 min, spouting 10 - 20 times, then submerge for 10 - 20 min. They are probably excellent divers. This species may reach 12.2 m in length, but target strength is unknown.

No tapes are available.

Hyperoodon ampullatus--(North Atlantic bottle-nose whale)

Sounds have only recently been recorded from the North Atlantic bottle-nose whale. The whistles and chirps are described as 115 - 850 msec long signals with most of their energy between 3 and 16 kHz. Some whistles stay at one frequency; others sweep through various frequencies. The constant frequency portions are mostly in the 3 to 5 kHz, 7 to 9 kHz, and 12 to 14 kHz range.

Clicks range in frequency from 500 Hz to above 26 kHz with the predominent energy at 8 - 12 kHz. There are 3 to 50 clicks per train with repetition rates up to 82 per sec. Click duration varies from 2 - 17 msec. No source level measurements have been made but the click sounds are reportedly very weak. No clicks were recorded when the whale-to-hydrophone distance was over 100 ft.

The bottle-nose whale is quite common in the North Atlantic, but it is rarely found in groups of more than 10 - 20 animals. Its "playful" nature and frequent breaching makes it fairly easy to spot at sea; however, its erratic swimming behavior makes it hard to follow for long periods of time.

This species, with individuals reaching 8 m, holds the record for the maximum duration of dive. Some observers claim this time to be 2 hours; however, few well documented records exceed 45 min - 1 hr. It is known to go down several hundred meters.

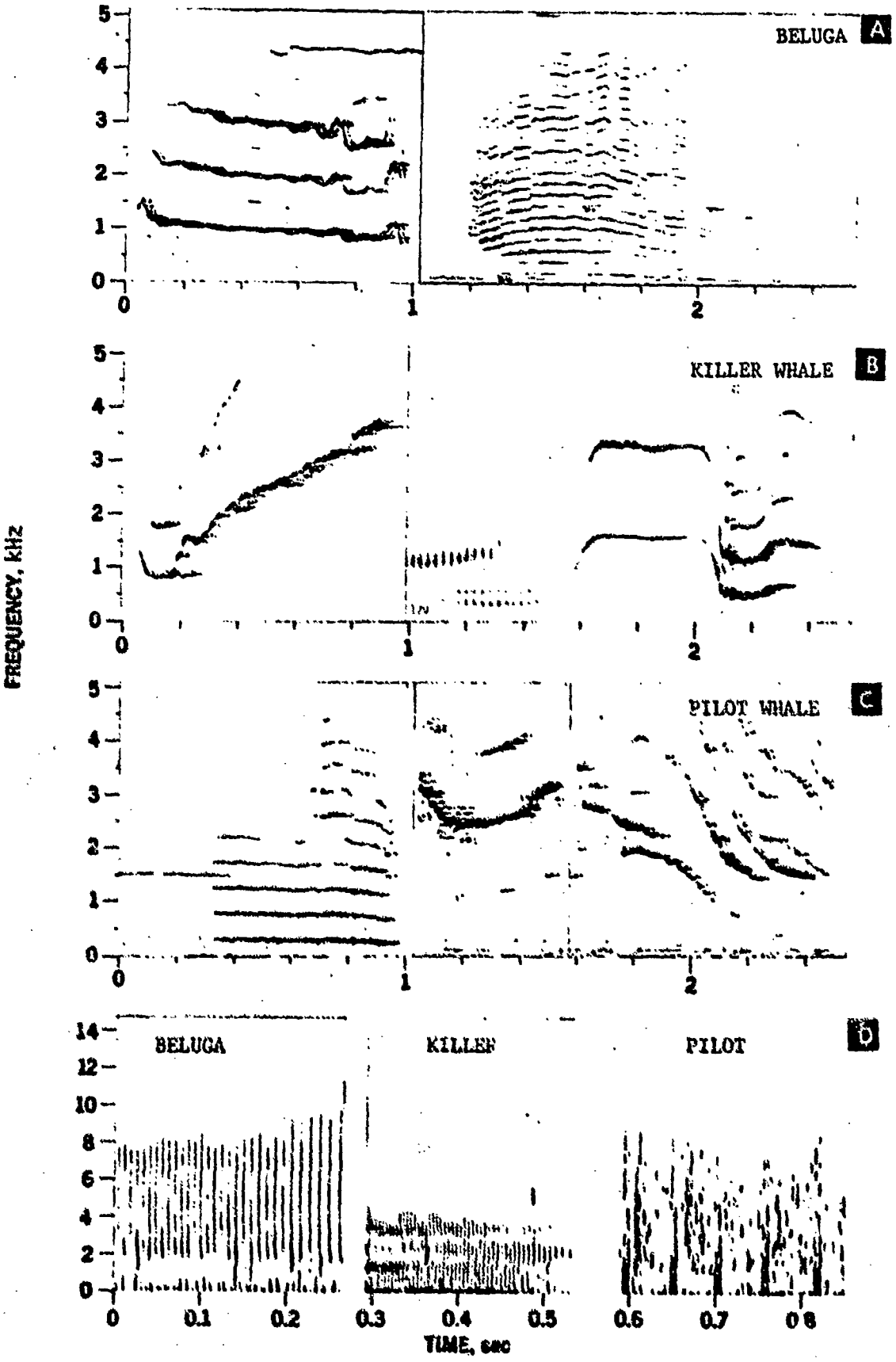
It is entirely possible that the North Atlantic bottle-nose whale can be found at area V year-round. Spring, however, is one of the most likely times. There is also a good chance of finding it at areas VI and VII but good information on its seasonal distribution is not available.

Since it is generally found in very small groups its sounds probably do not contribute much to the ambient noise level of an area. Tape recordings

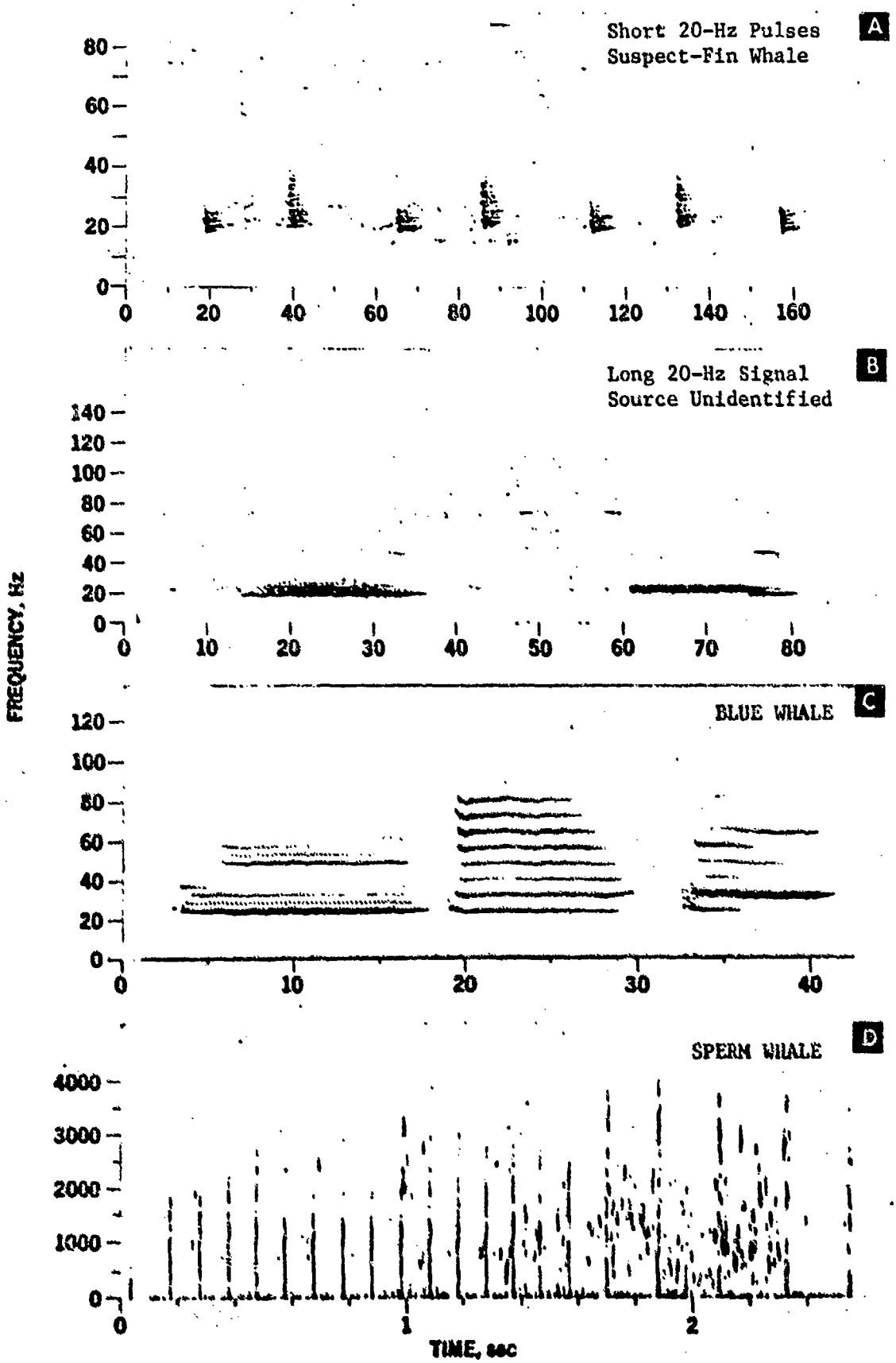
Hyperoodon ampullatus--(North Atlantic bottle-nose whale) continued

of the sounds are available from Dr. H. E. Winn, Graduate School of Oceanography, University of Rhode Island. A copy of the tape has been acquired by Dr. J. F. Fish, NUC Code 5054.

REPRESENTATIVE SONAGRAMS OF WHALE SOUNDS


BELUGA
A
KILLER WHALE
B
PILOT WHALE
C
FREQUENCY, kHz
BELUGA
KILLER
PILOT
D
TIME, sec

BIOACOUSTICS



SUMMARY AND CONCLUSIONS BY AREA

The following species of marine mammals are known to be soniferous; magnetic tape recordings of their sounds are available; and they can be expected to occur at each of the indicated areas ("good chance" or better of occurrence). They represent the best candidates for each location.

Given the particulars concerning intended applications and the information presented in this report, a final choice of candidates can be made for each area. NUC Code 5054 can assist in making these final choices.

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